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FREQUENCY DEPENDENT BOTTOM LOSS AND MARINE SEDIMENT ATTENUATION--ETC(U)
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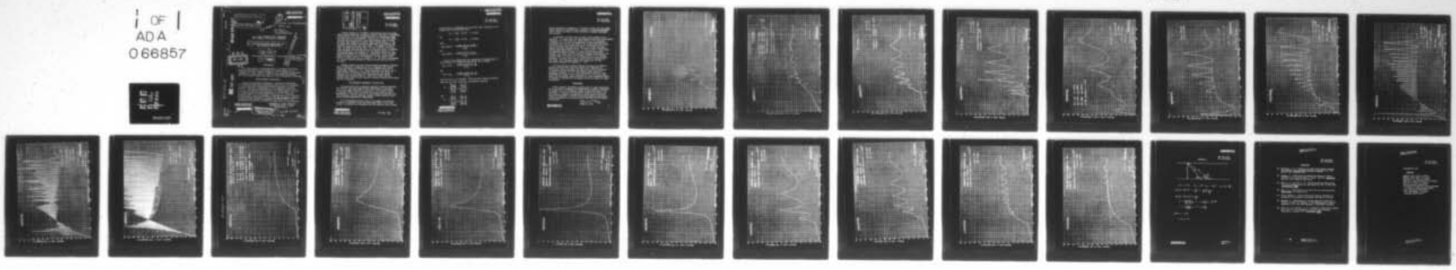

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U. S. NAVY UNDERWATER SOUND LABORATORY
FORT TRUMBULL, NEW LONDON, CONNECTICUT

6 FREQUENCY DEPENDENT BOTTOM LOSS AND MARINE SEDIMENT ATTENUATION

By

10 B. F./Cole

USL Technical Memorandum No. 905-032-64

11 2 Apr[redacted]64

12 26p.

The opinions expressed are those of the author(s) and not necessarily the official views of the Laboratory.

ABSTRACT

INTRODUCTION

It is the purpose of this memorandum (1) to assert that marine sediment attenuation is proportional to the first power of the frequency for a given sample of sediment, (2) to explain the frequency dependence of bottom loss as a result of this linear relationship, and (3) to present bottom loss curves for other frequencies of interest.

ABSTRACT

MARINE SEDIMENT ATTENUATION

Since bottom sediment attenuation or absorption coefficients are generally determined at frequencies above 20 kc, it is necessary to obtain absorption coefficients at lower frequencies by extrapolation. The lack of measurements at low frequencies leaves the method of extrapolation arbitrary, but it is usually agreed that the attenuation in water-saturated sediments is proportional to the frequency raised to a power ranging from 0.5 to 2.0. Mackenzie (reference (a)), using a comparison of experimental data and modified Rayleigh curves, has further concluded that the attenuation should be extrapolated from Shumway's measurements (reference (b)) to the frequency of interest "as the first or higher power of the frequency."

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Various attempts to fit BRASS II experimental bottom loss data using a three-layer model (reference (c)) have indicated, in accordance with Mackenzie, that the attenuation should be extrapolated using the first power of the frequency. This use of a three-layer model requires that the thickness of the first sediment layer be known, but since this thickness is usually varied parametrically, it can be argued that another theoretical combination of attenuation and thickness could produce the same results. The BRASS II Station V, (Fig. 1) presents an unusual case. The well defined bottom loss curve and small standard deviation for each point allow a reasonable layer thickness to be calculated from the angular spacing of the interference peaks (see Appendix A). Theoretical curves were then computed considering the attenuation proportional to the one-half, first, and second power of the frequency, and are compared with Station V bottom loss data in Figures 2 - 4. The curve corresponding to a linear frequency dependence clearly provides the best fit to the data.

Further evidence for this linear frequency-attenuation relationship is supplied by comparisons of Fry's (reference (d)) Pacific bottom loss curves and theoretical curves computed using such a relationship (Figures 5 - 10). These comparisons are shown, not to imply that the theoretical values match the data, but merely to indicate that the theoretical and experimental curves change similarly with varying frequency. Since the Pacific data was analyzed using logit filters, discrete frequency interference patterns can not be expected.

THE FREQUENCY DEPENDENCE OF BOTTOM LOSS

Although bottom loss is usually considered frequency dependent, the loss for some areas appears nearly independent of frequency over a wide range (references (e) and (f)). In contrast, bottom reverberation, which should correlate with bottom loss, is found independent of frequency with one or two exceptions (reference (g)). Such excursions from the ordinary, however, follow directly from a linear frequency-attenuation relationship.

It is advantageous at this point to re-examine the equations presented in reference (c) for the three-layer model of the ocean bottom. Attenuation was introduced into the second and third layers

of this model by considering the respective layer velocities to be complex and of the following form:

$$C_2 = |C_2| \ (\cos \phi_2 - i \sin \phi_2)$$

and

$$C_3 = |C_3| \ (\cos \phi_3 - i \sin \phi_3)$$

where

$$\alpha_2 \text{ (db/ft)} = \frac{8.6858 \ (2\pi f) \ \tan \phi_2}{|C_2|}$$

and

$$\alpha_3 \text{ (db/ft)} = \frac{8.6858 \ (2\pi f) \ \tan \phi_3}{|C_3|} .$$

If it is now assumed that the attenuation is proportional to the frequency, the frequency terms cancel, and we obtain:

$$\alpha_2 = K_2 \cancel{f} = \frac{8.6858 \ (2\pi \cancel{f}) \ \tan \phi_2}{|C_2|}$$

and

$$\alpha_3 = K_3 \cancel{f} = \frac{8.6858 \ (2\pi \cancel{f}) \ \tan \phi_3}{|C_3|}$$

where K_2 and K_3 are constants. Thus the layer complex velocities and hence the layer reflection coefficients, given by:

$$R_1 = \frac{\dfrac{\rho_2 C_2}{\cos \theta_2} - \dfrac{\rho_1 C_1}{\cos \theta_1}}{\dfrac{\rho_2 C_2}{\cos \theta_2} + \dfrac{\rho_1 C_1}{\cos \theta_1}}$$

and

$$R_2 = \frac{\dfrac{\rho_3 C_3}{\cos \theta_3} - \dfrac{\rho_2 C_2}{\cos \theta_2}}{\dfrac{\rho_3 C_3}{\cos \theta_3} + \dfrac{\rho_2 C_2}{\cos \theta_2}}$$

become independent of frequency. It should be noted that the steady-state reflection coefficient still contains a frequency-attenuation term by taking the ratio of layer thickness to complex wavelength into account.

A discussion of bottom loss in view of these results is now warranted. In areas where the water-sediment interface is the dominant reflector, the bottom loss will depend mostly on the reflection coefficient, R_1, and will be independent or nearly independent of frequency, but in areas where most of the energy enters the bottom and is reflected from a sub-bottom layer, the bottom loss then becomes frequency dependent due to the ratio of layer thickness to complex wavelength mentioned above. In other words, in areas where the immediate bottom consists of a high velocity sand or silt sediment, the bottom loss will approach frequency independence, but in areas where these sand or silt layers underlie a low velocity sediment layer of clay or silt, the bottom loss will be frequency dependent. In these latter areas, which appear to dominate the deep ocean, this frequency effect will slowly damp out with increasing frequency (see Figures 11 - 19).

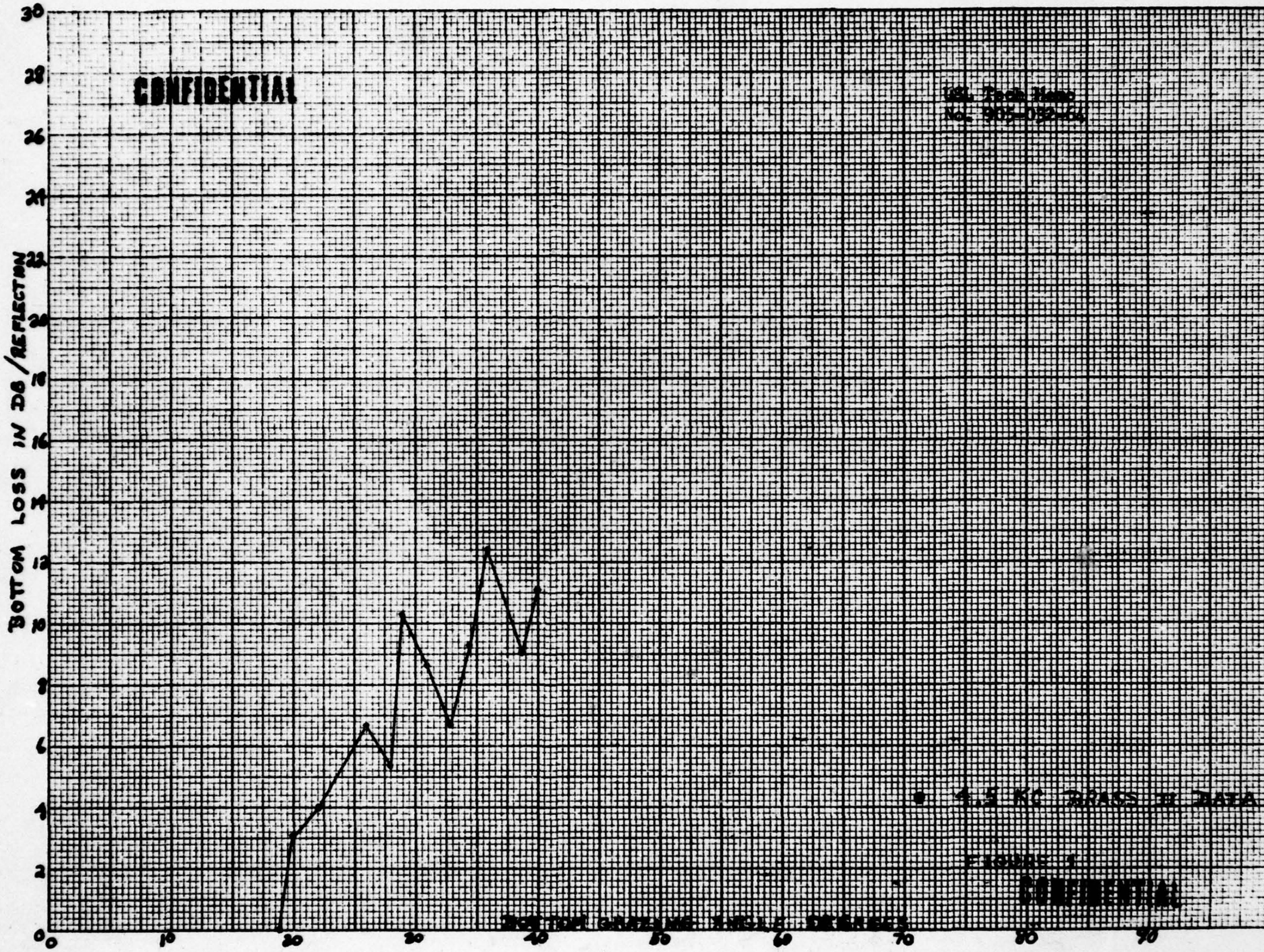
The good agreement obtained between theoretical and BRASS II Station V bottom loss values has prompted the computation of theoretical bottom loss curves for this area at other frequencies of interest in sonar operation and design. These curves are presented as Figures 11 - 19. Since the BRASS II Station V data represents the lowest bottom loss values at 4.5 kc for deep water areas, the theoretical curves presented for other frequencies should be regarded as minimum and not average bottom loss curves for these frequencies.

CONCLUSIONS

Marine sediment attenuation coefficients for sonar frequencies can be accurately determined from measurements at higher frequencies by assuming that the attenuation varies as the first power of the frequency. It follows from this linear relation that bottom loss will approach frequency independence in areas where bottom penetration is negligible, and will be frequency dependent where major energy contributions are received from a reflector at some depth in the sediment.

Bernard F. Cole
ygl

BERNARD F. COLE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No. 905-032-64
BOTTOM LOSS IN DB/REFLECTION
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
BOTTOM GRAZING ANGLE DEGREES
0
10
20
30
40
50
60
70
80
90
● 4.5 KC BRASS II DATA
CONFIDENTIAL

FIGURE 1

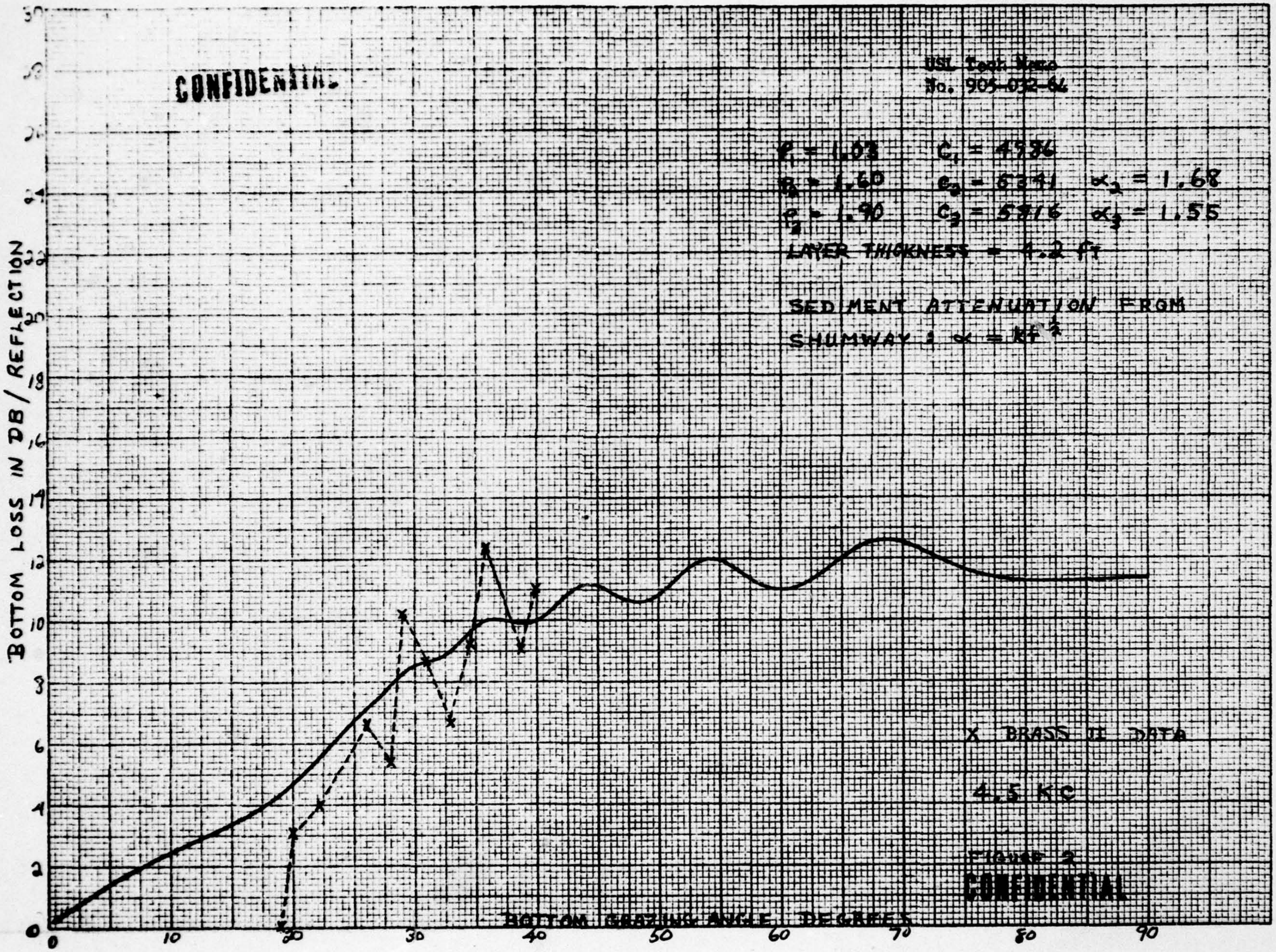

Figure 2
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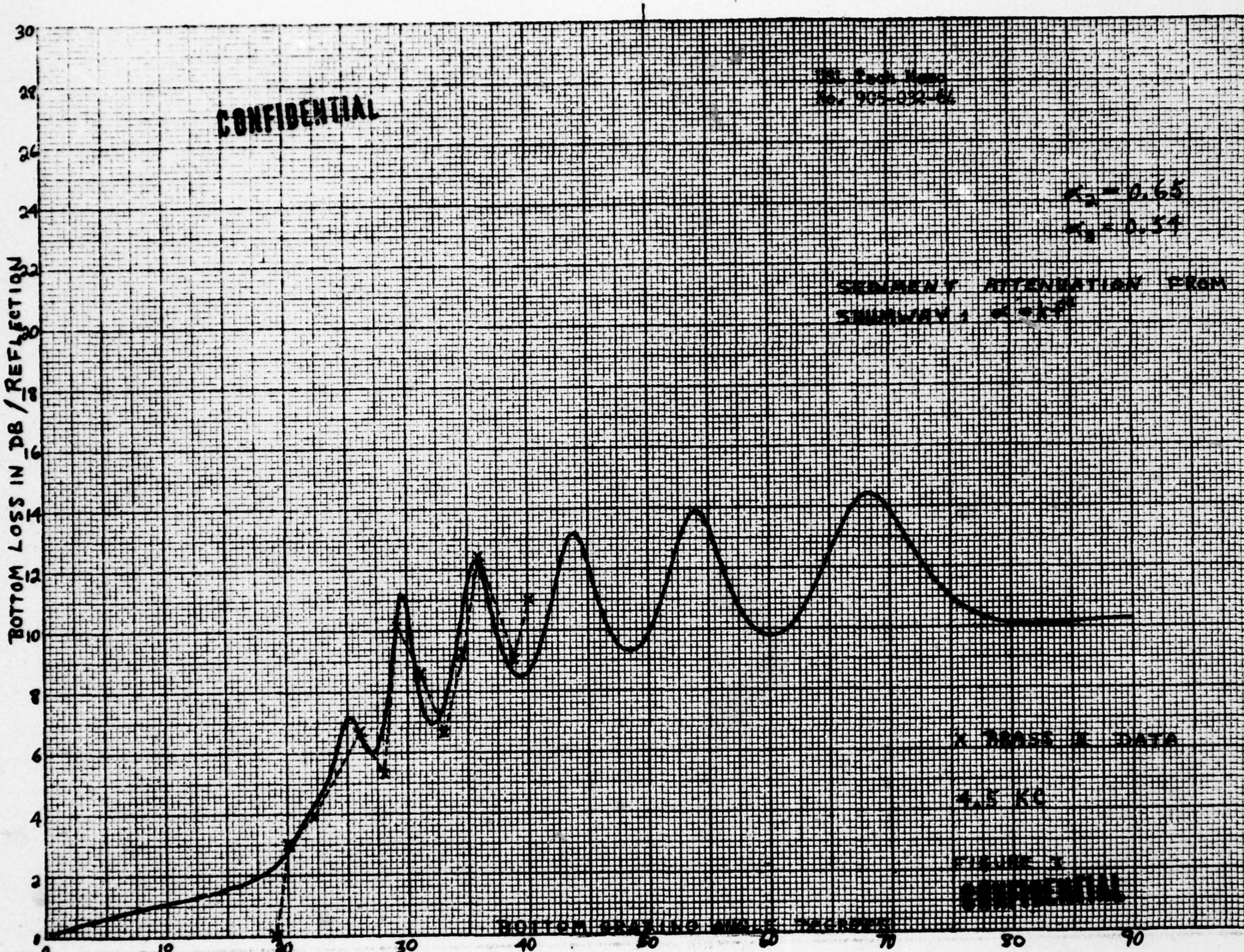
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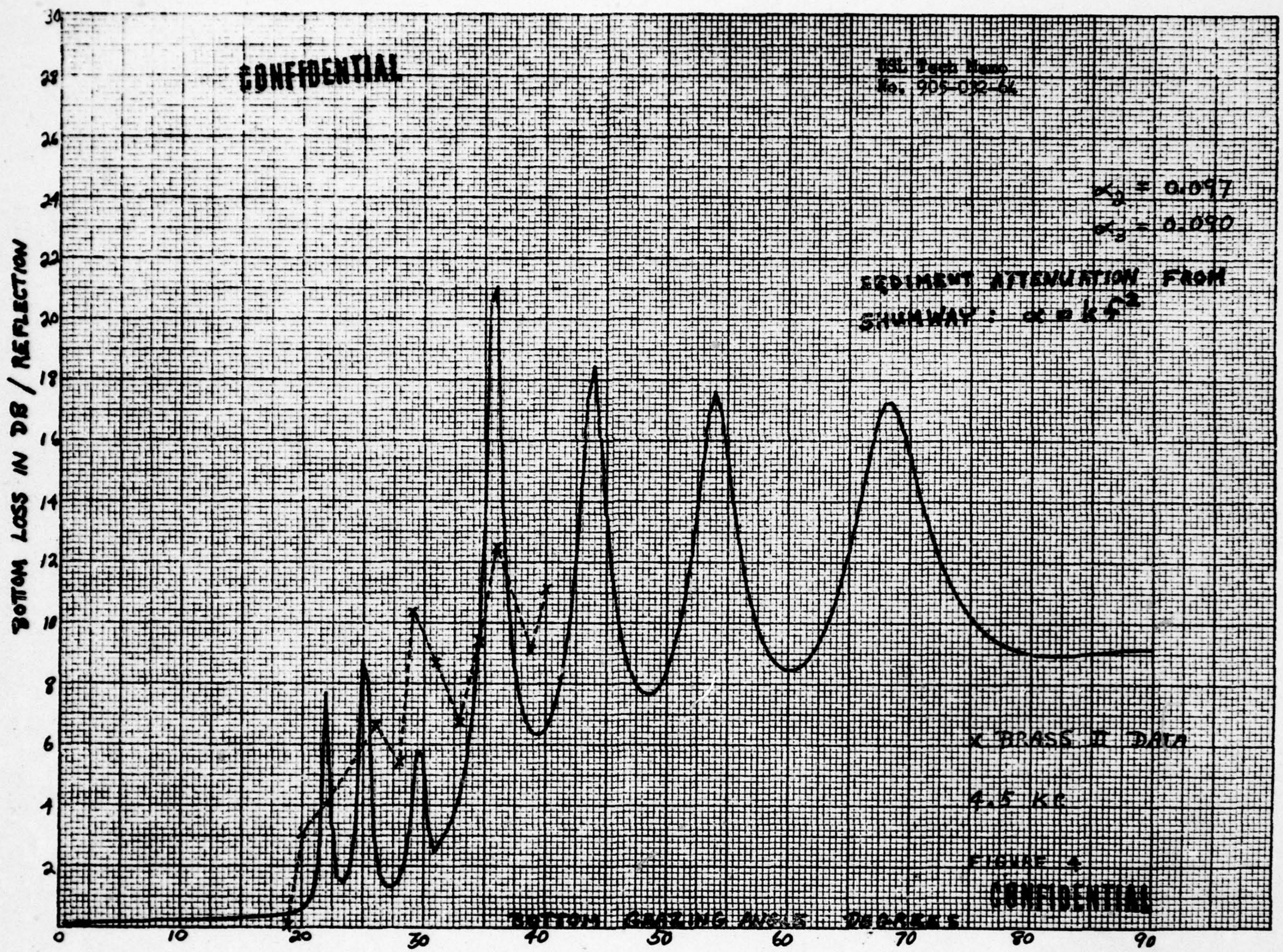
USL Tech Memo
No. 905-032-64
BOTTOM LOSS IN DB / REFLECTION
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
10
20
30
40
50
60
70
80
90
X BRASS II DATA
4.5 KC
BOTTOM GRAZING ANGLE DEGREES
CONFIDENTIAL
FIGURE 3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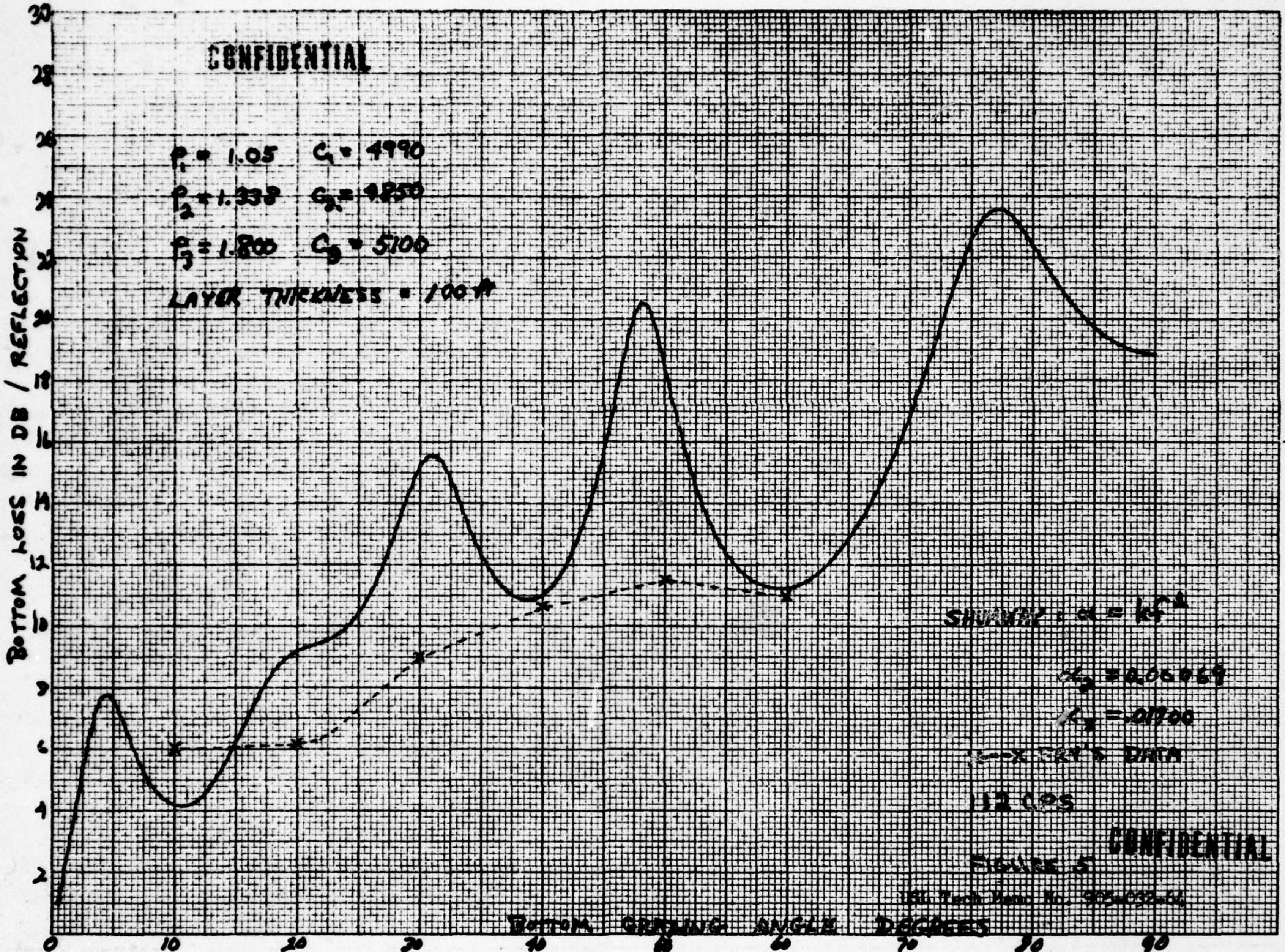
No. 905-032-64
$\alpha_2 = 0.097$
$\alpha_3 = 0.090$
SEDIMENT ATTENUATION FROM
SHUMWAY : $\alpha = kf^2$
X BRASS II DATA
4.5 KC
FIGURE 4
CONFIDENTIAL
BOTTOM LOSS IN DB / REFLECTION
BOTTOM GRAZING ANGLE DEGREES
0
10
20
30
40
50
60
70
80
90
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30


CONFIDENTIAL
$\rho_1 = 1.05$ $C_1 = 4990$
$\rho_2 = 1.338$ $C_2 = 4850$
$\rho_3 = 1.800$ $C_3 = 5100$
LAYER THICKNESS = 100 ft
BOTTOM LOSS IN DB / REFLECTION
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
10
20
30
40
50
60
70
80
90
BOTTOM GRAZING ANGLE DEGREES
SHUMWAY : $\alpha = kf^{\lambda}$
$k_2 = 0.00069$
$k_3 = .01700$
X--X DATA
112 CPS
CONFIDENTIAL
FIGURE 5
USL Tech Memo No. 905-032-64

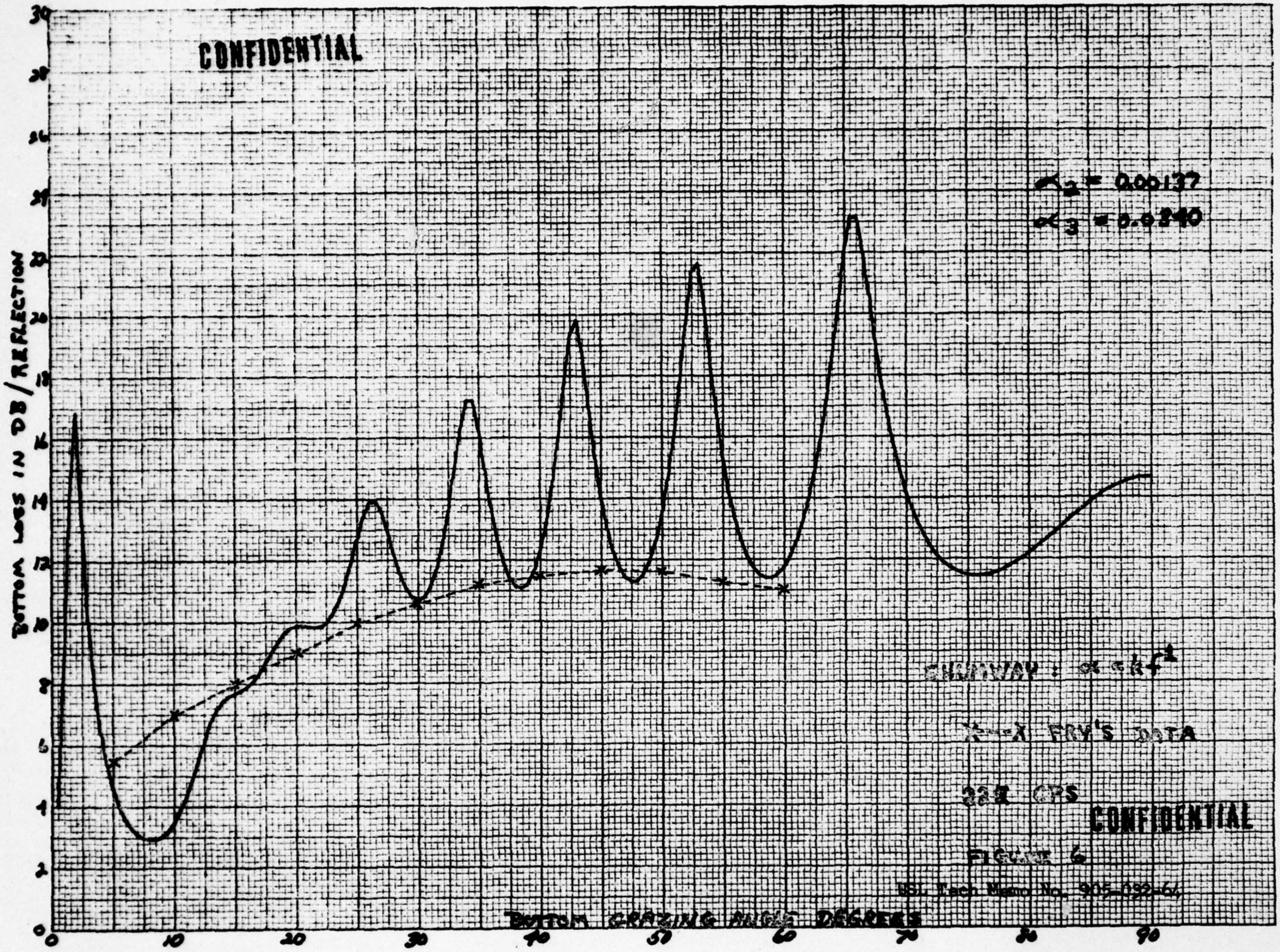


FIGURE 6

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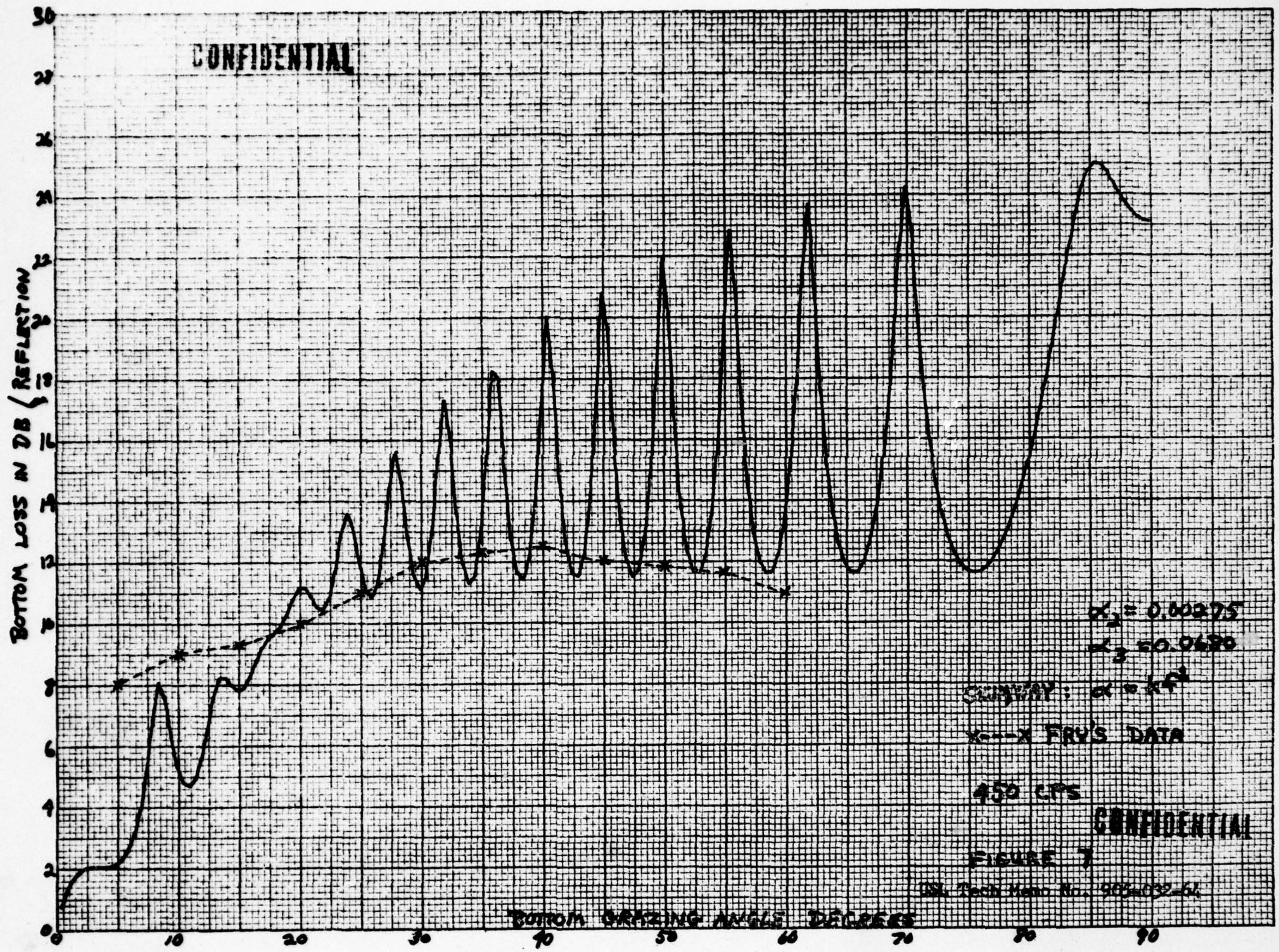

FIGURE 7

USL Tech Memo No. 905-032-61

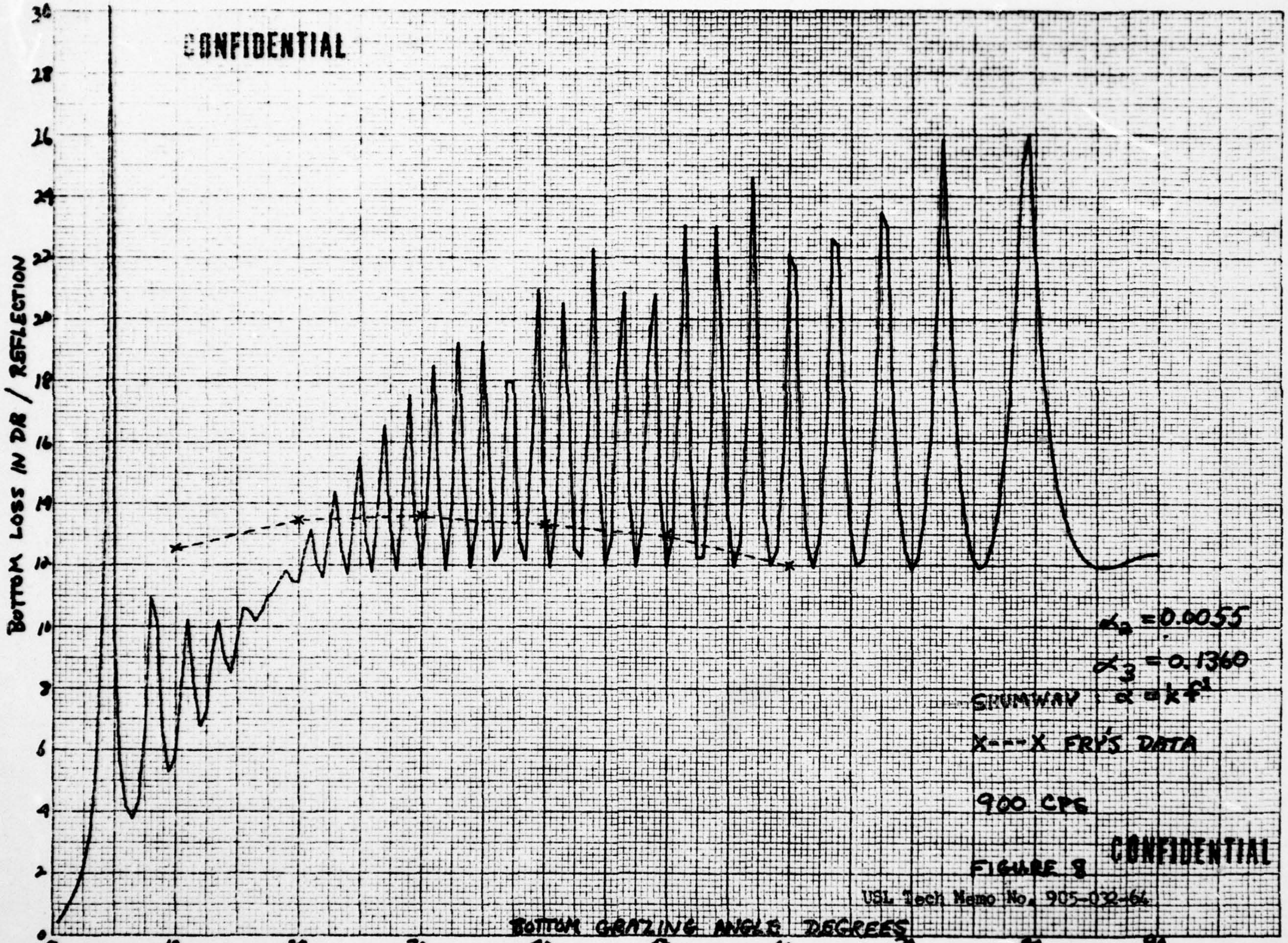

FIGURE 8

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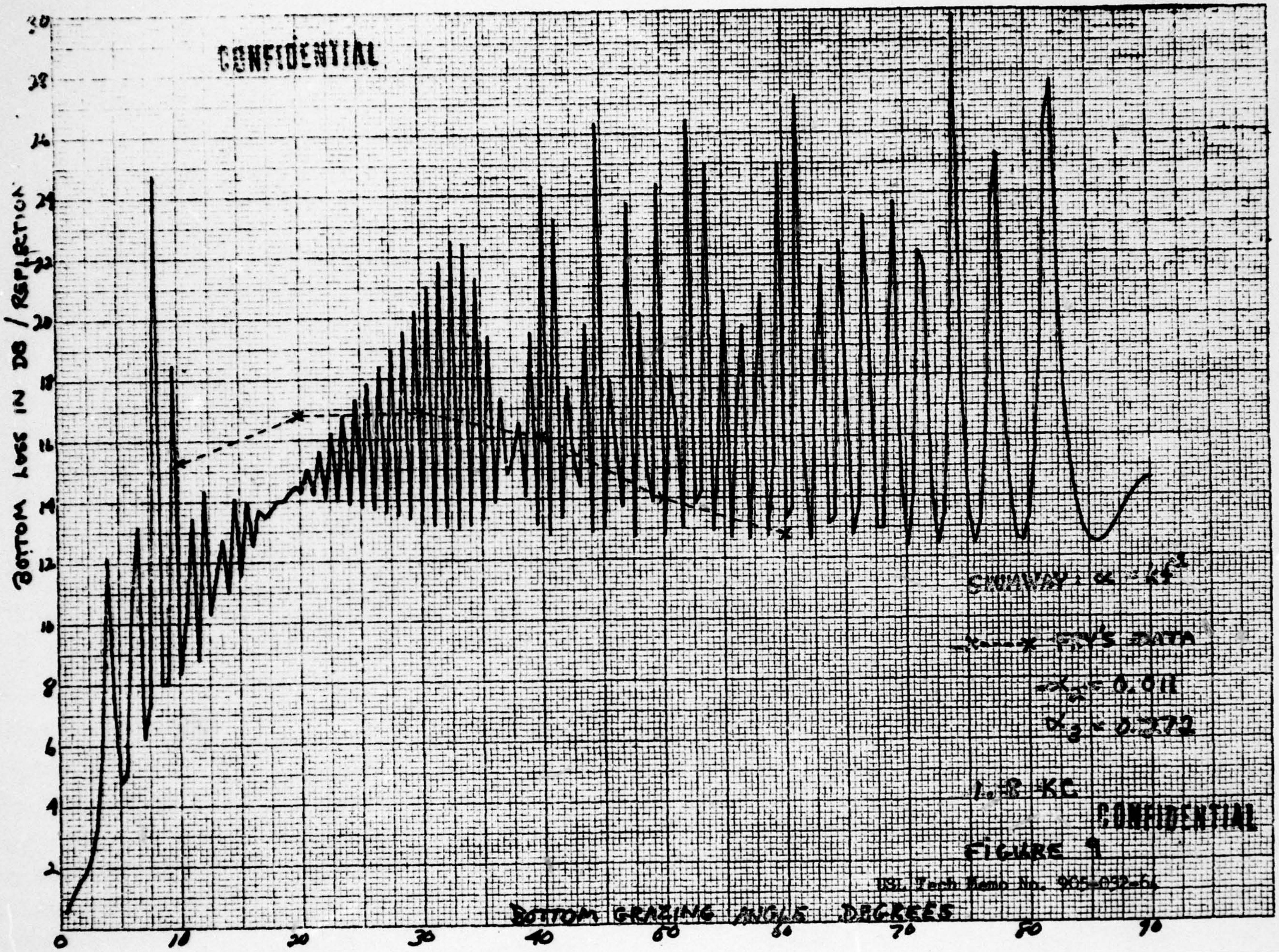

FIGURE 9

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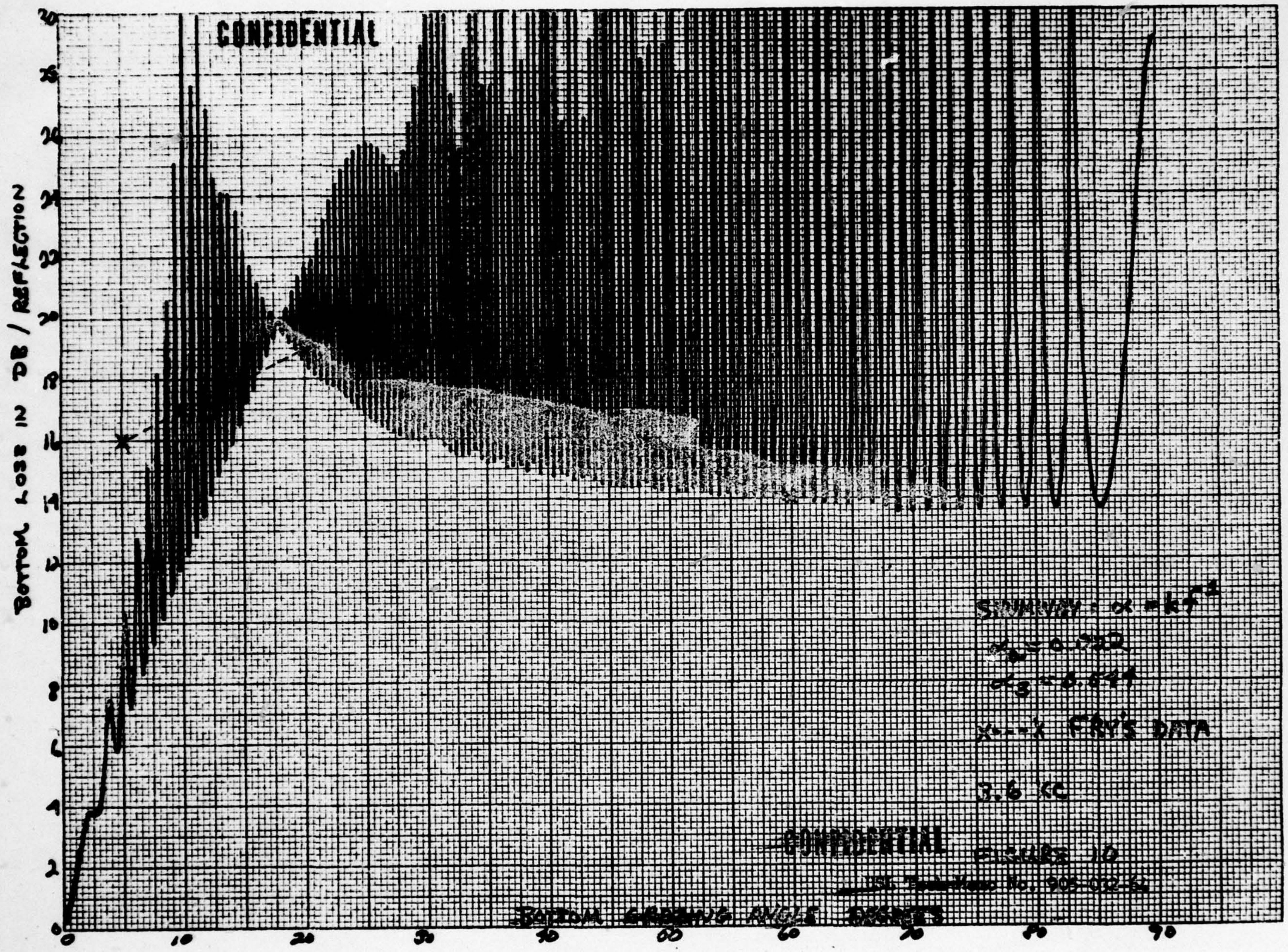
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BOTTOM LOSS IN DB / REFLECTION
BOTTOM GRAZING ANGLE DEGREES
X--X FRY'S DATA
3.6 KC
CONFIDENTIAL
FIGURE 10
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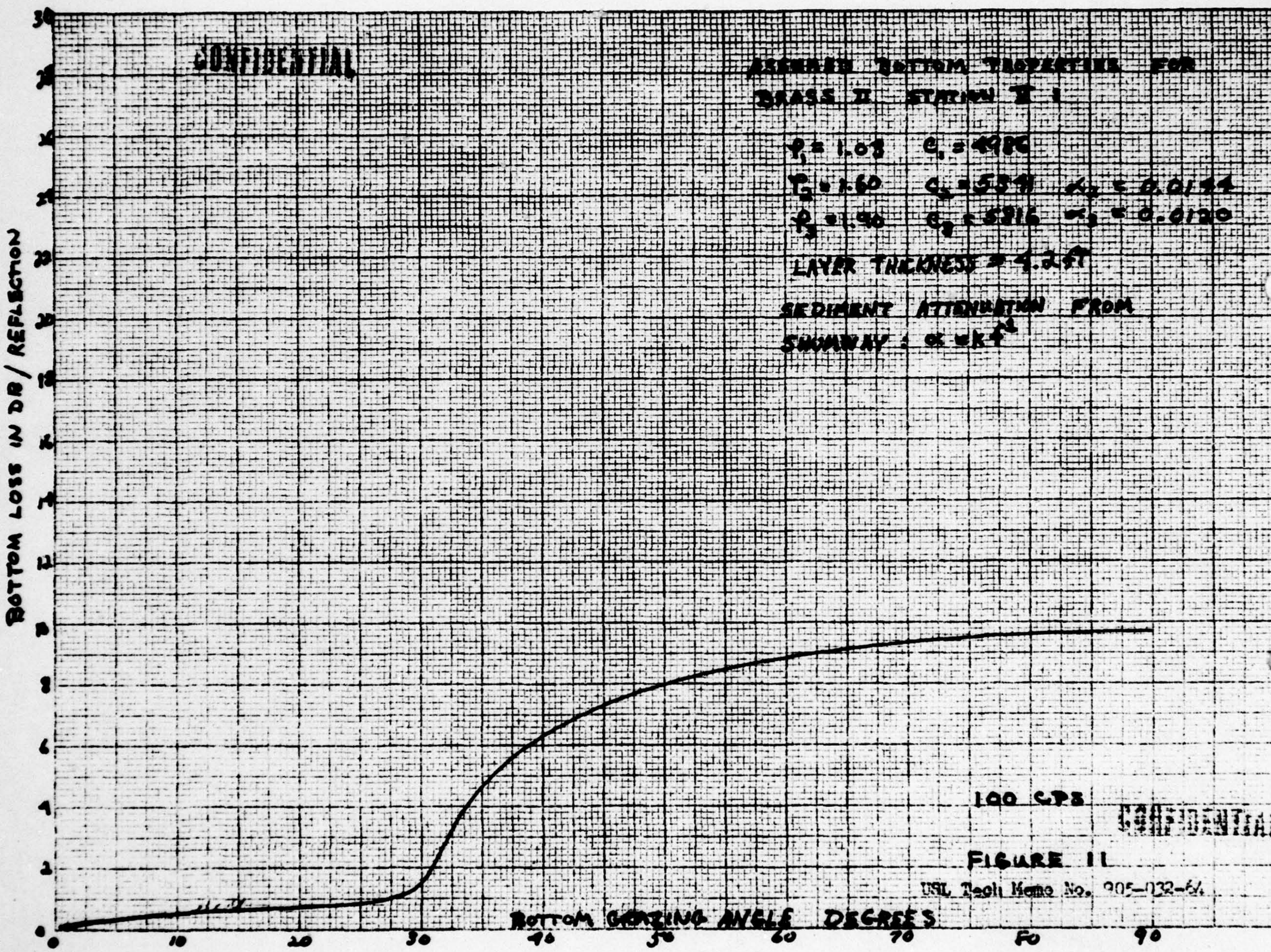

FIGURE 11

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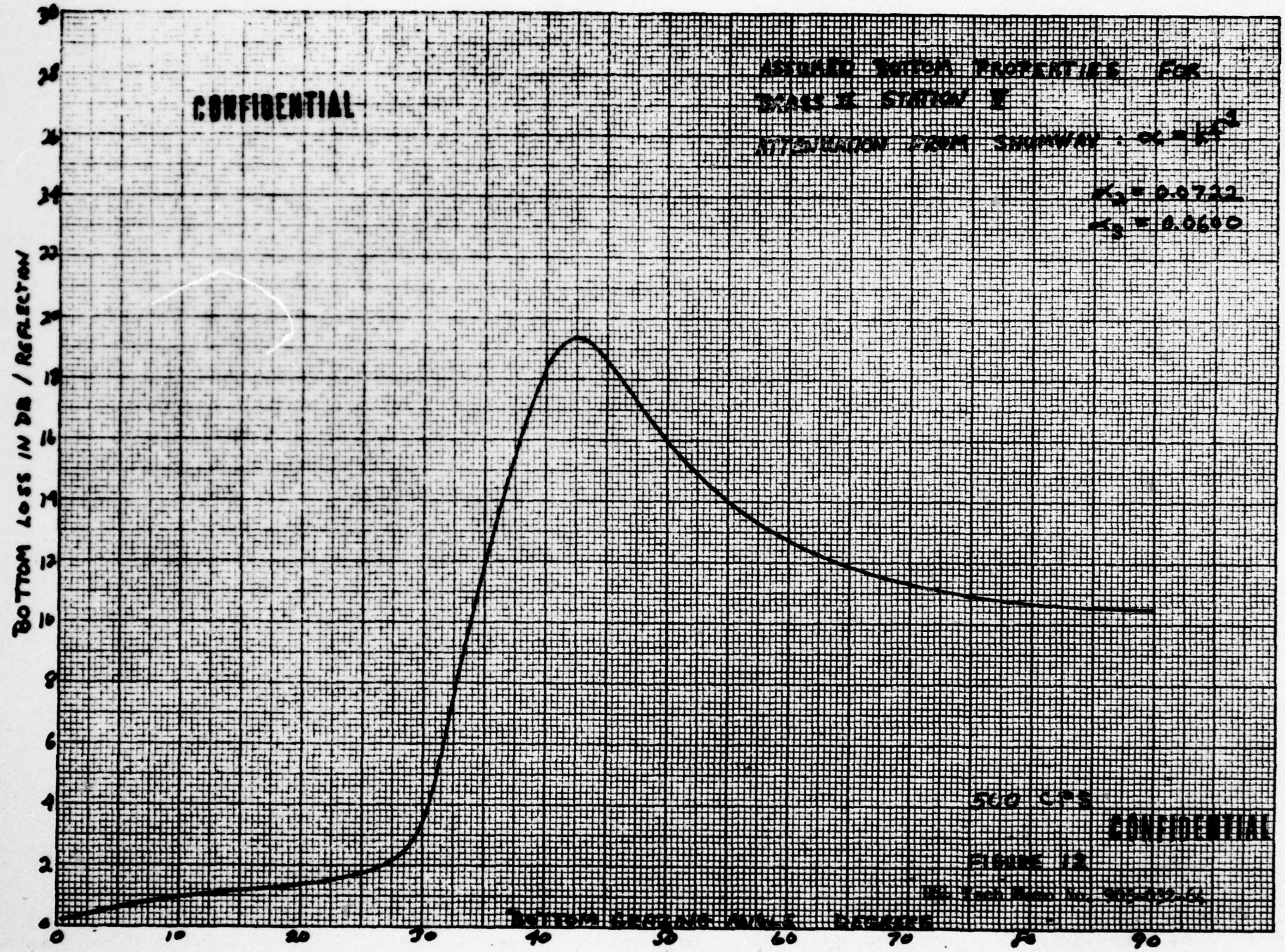
ASSUMED BOTTOM PROPERTIES FOR
ATTENUATION FROM SHUMWAY
= 0.0722
= 0.0600
500 CPS
BOTTOM LOSS IN DB / REFLECTION
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0
10
20
30
40
50
60
70
80
90

FIGURE 12

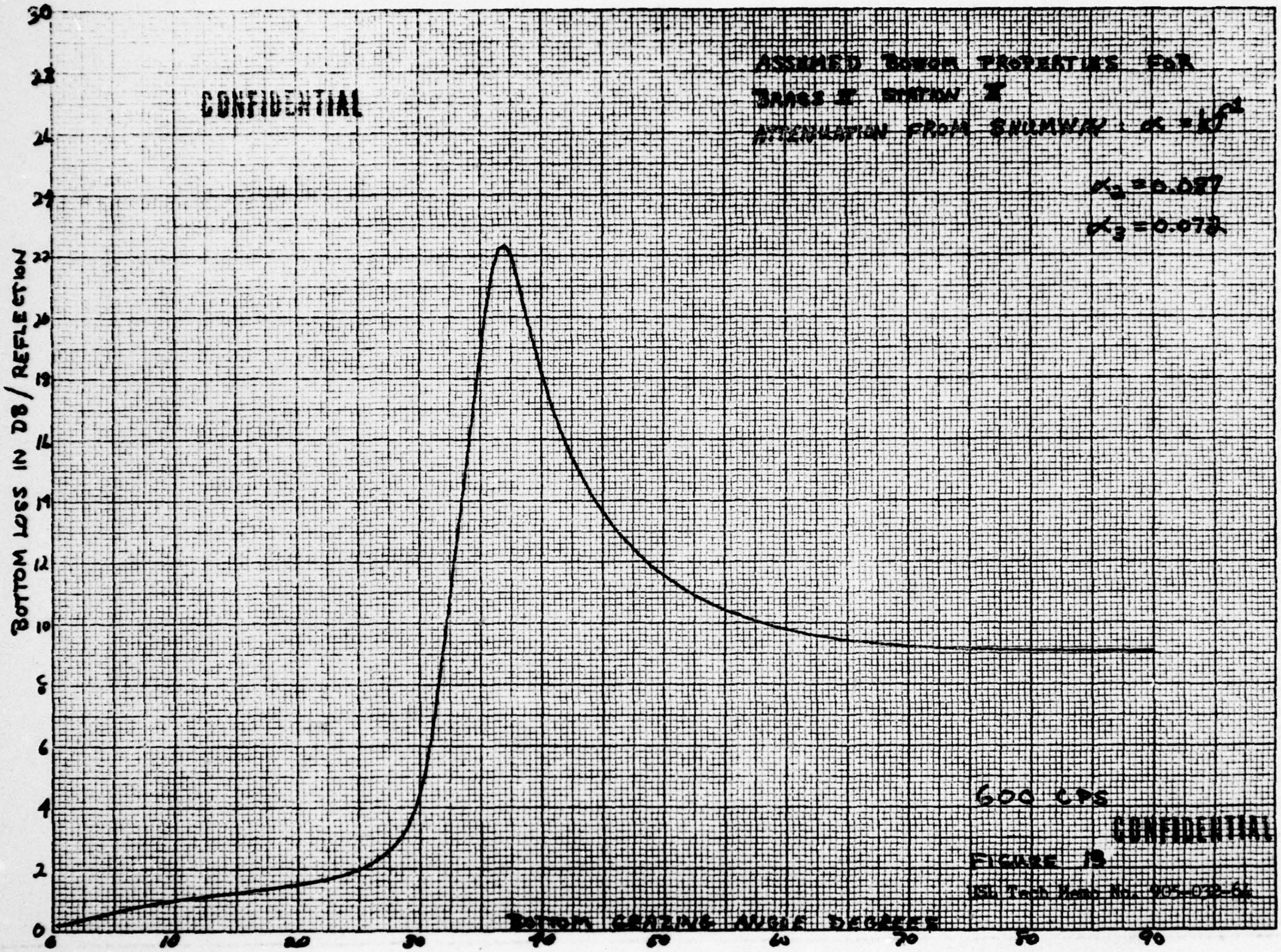

FIGURE 13

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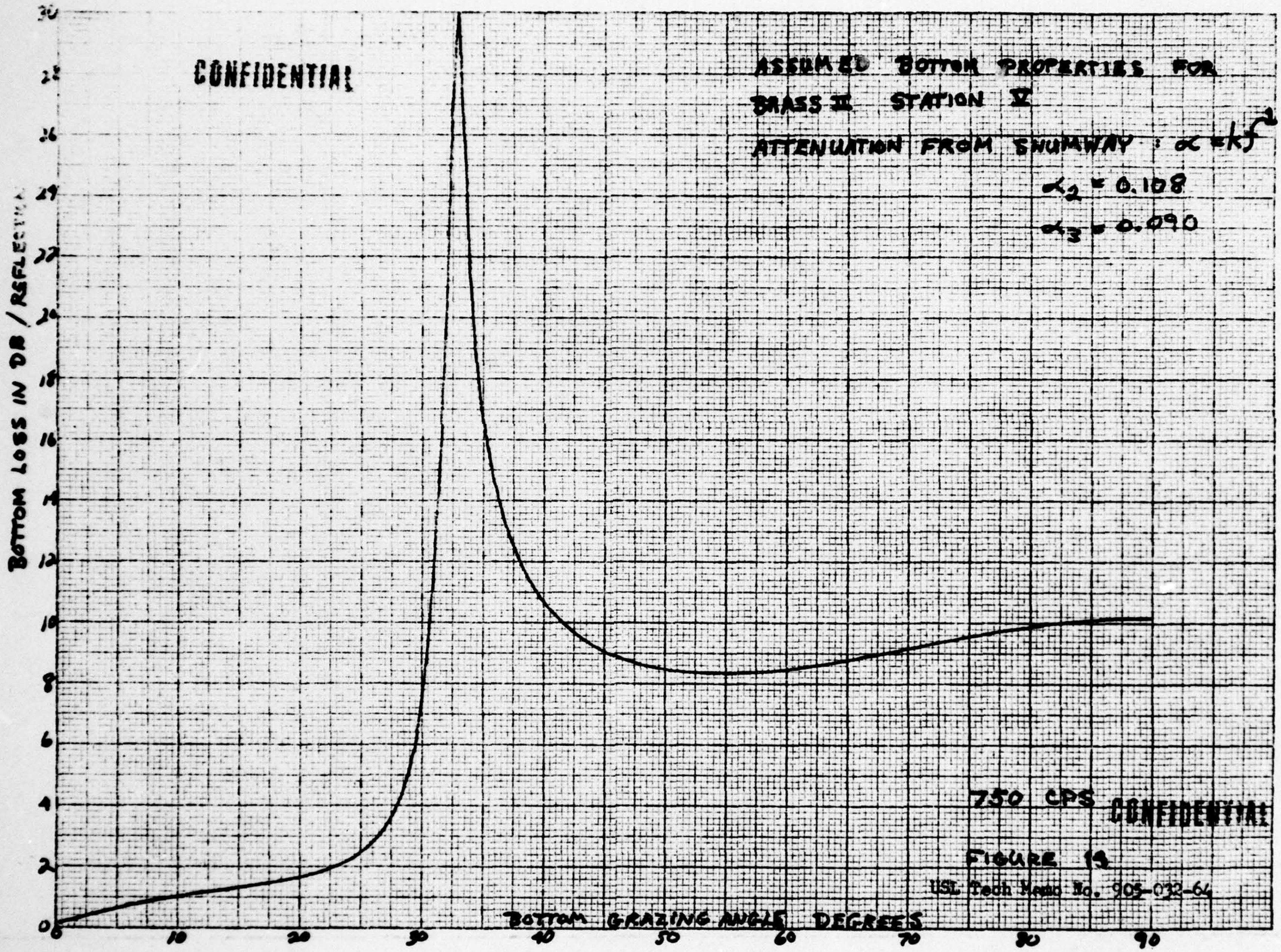

FIGURE 19

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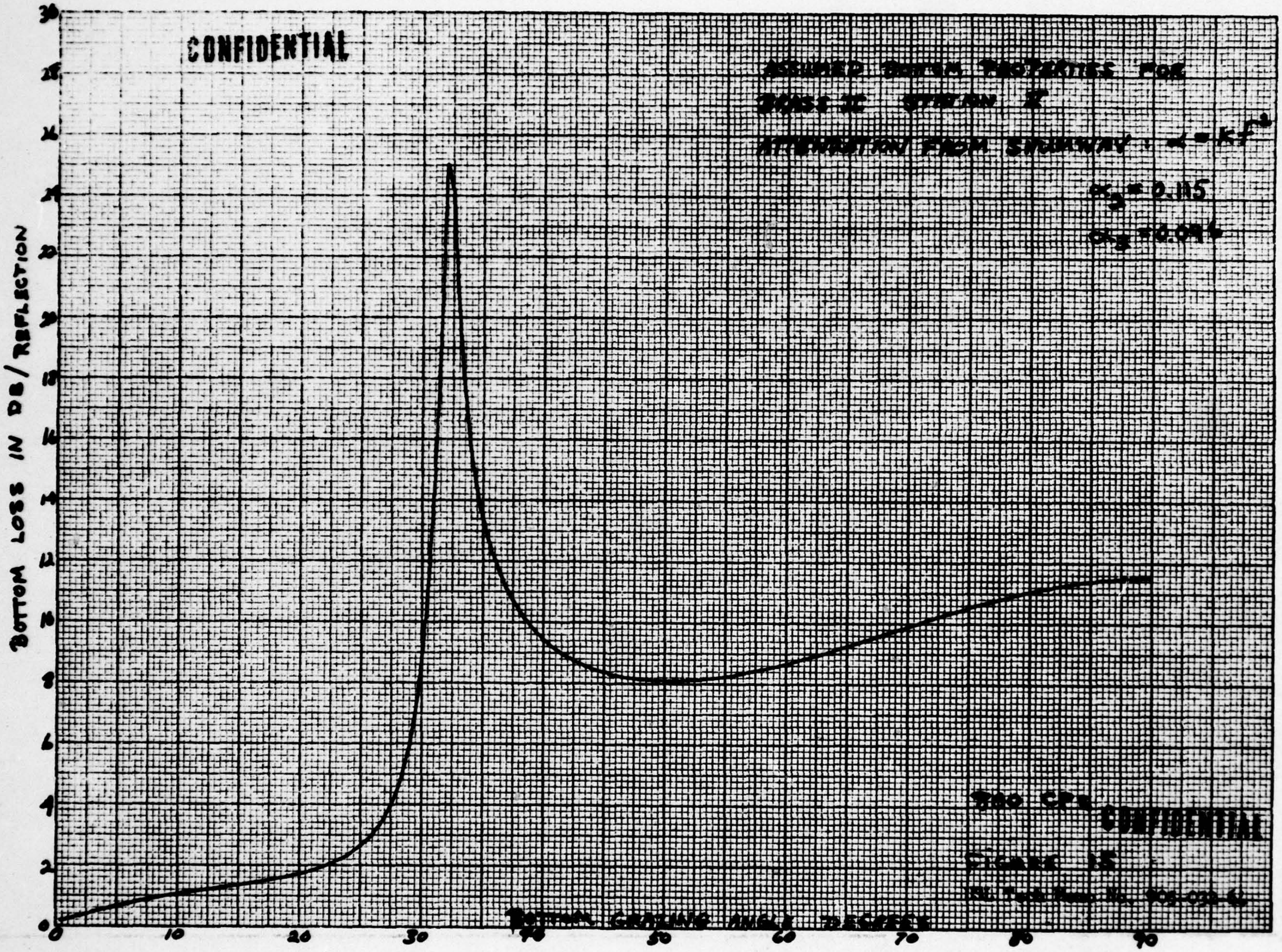
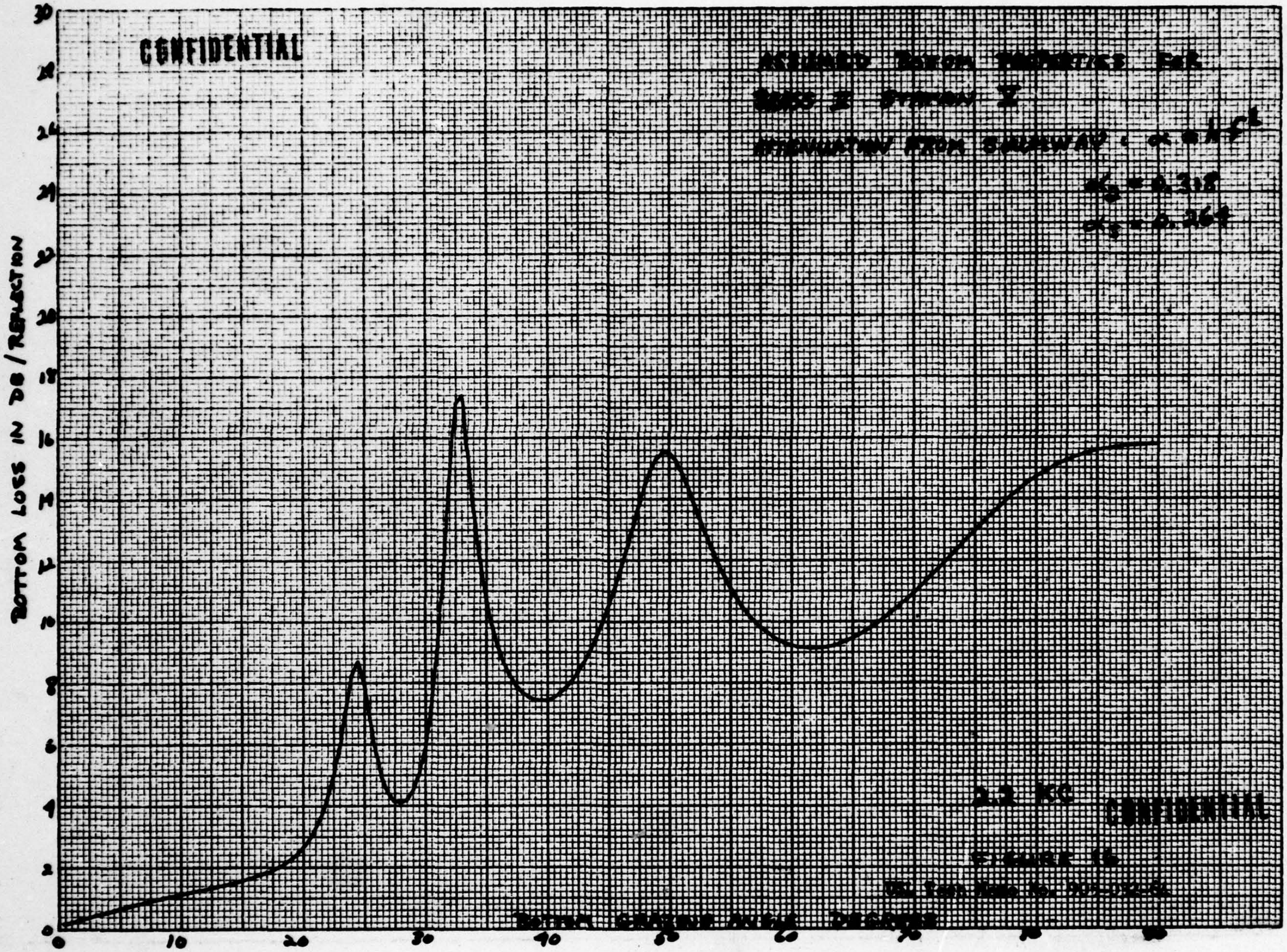
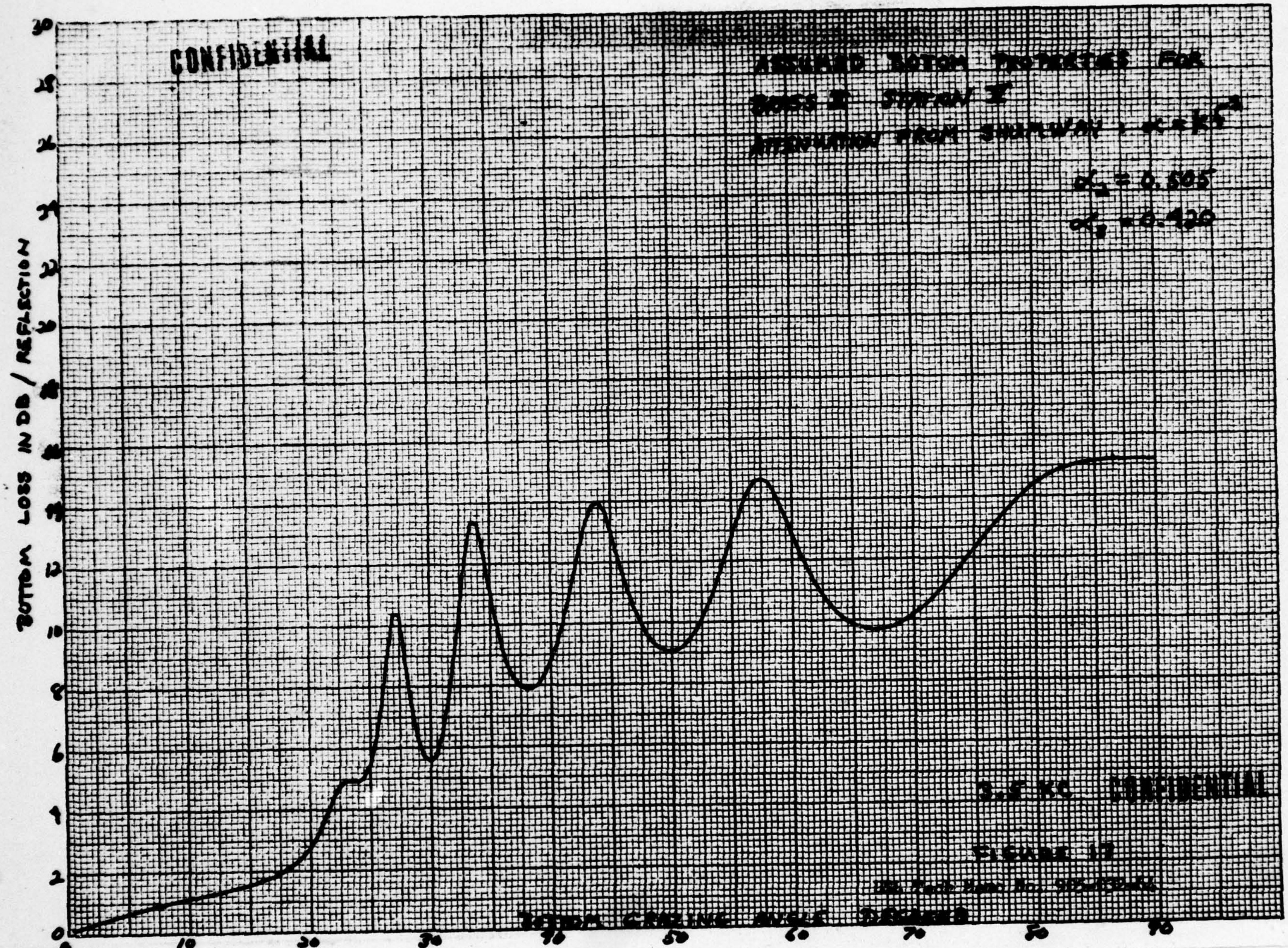
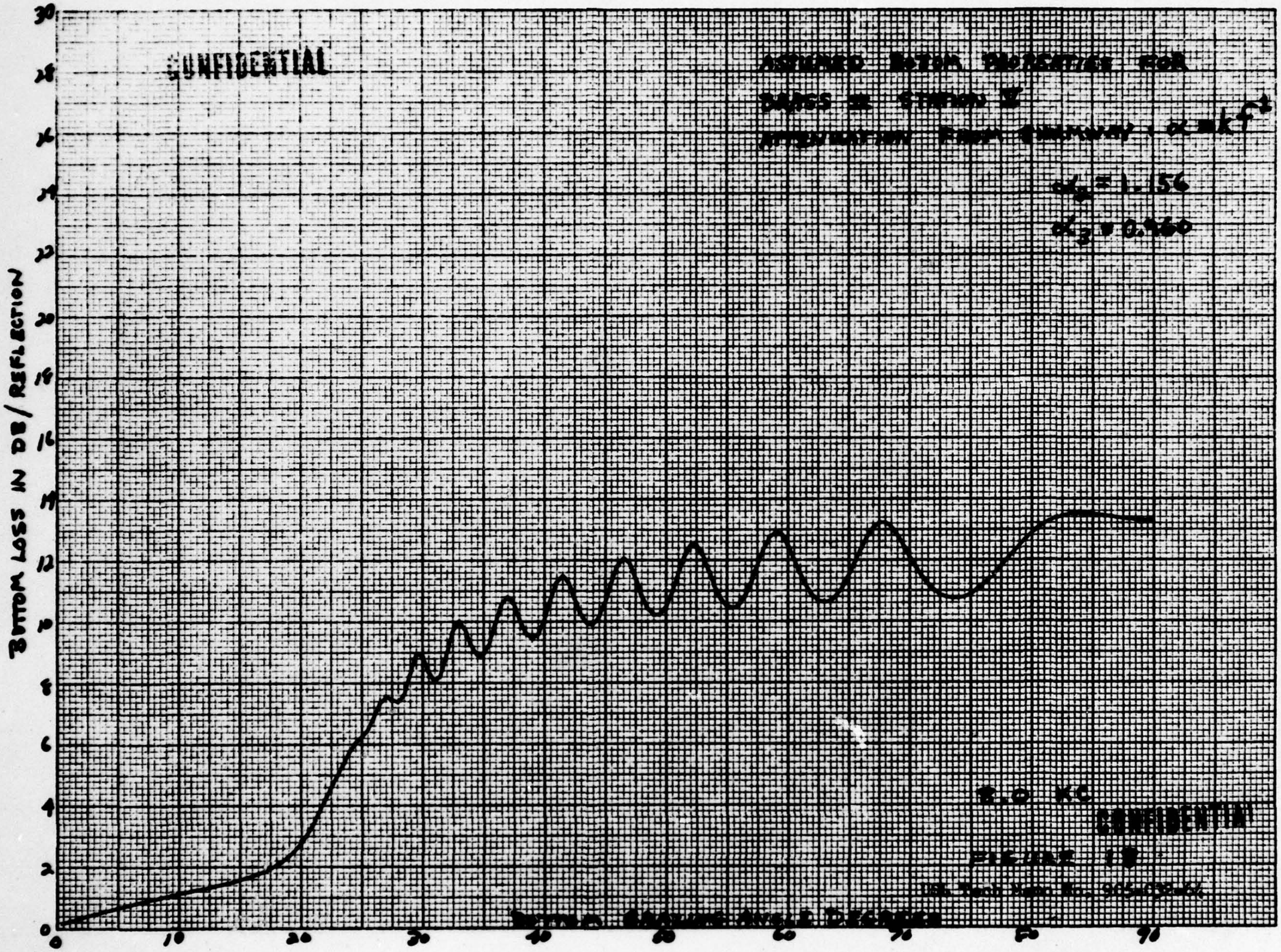
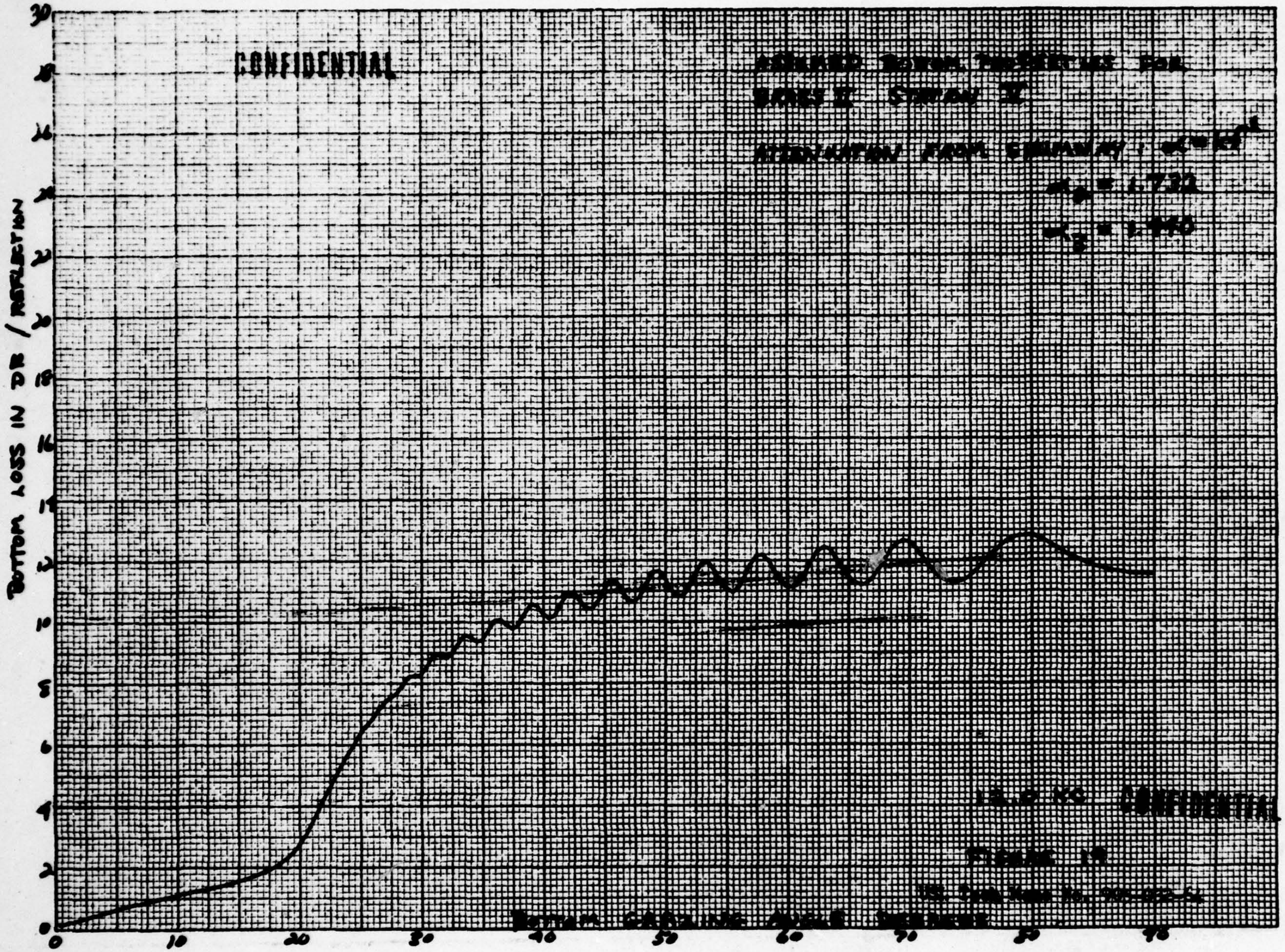

CONFIDENTIAL
ASSUMED BOTTOM PROPERTIES FOR
ATTENUATION FROM SHUMWAY : $\alpha = kf^2$
$\alpha_3 = 0.115$
CPS
CONFIDENTIAL
FIGURE 15
BOTTOM LOSS IN DB/REFLECTION
BOTTOM GRAZING ANGLE DEGREES
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
10
20
30
40
50
60
70
80
90


CONFIDENTIAL
BOTTOM LOSS IN DB/REFLECTION
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0
10
20
30
40
50
60
70
80
90
BOTTOM GRAZING ANGLE DEGREES
2.2 KC
CONFIDENTIAL
FIGURE 16


CONFIDENTIAL
ASSUMED BOTTOM PROPERTIES FOR
BOSS II STATION I
ATTENUATION FROM SHUMWAY
$\alpha_2 = 0.505$
$\alpha_3 = 0.420$
3.5 KC CONFIDENTIAL
BOTTOM LOSS IN DB / REFLECTION
BOTTOM GRAZING ANGLE DEGREES
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0
10
20
30
40
50
60
70
80
90
FIGURE 17


CONFIDENTIAL
ASSUMED BOTTOM PROPERTIES FOR
STATION
$\alpha_2 = 1.156$
$\alpha_3 = 0.460$
KC
CONFIDENTIAL
FIGURE
BOTTOM LOSS IN DB/REFLECTION
BOTTOM GRAZING ANGLE DEGREES
0
10
20
30
40
50
60
70
80
90
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30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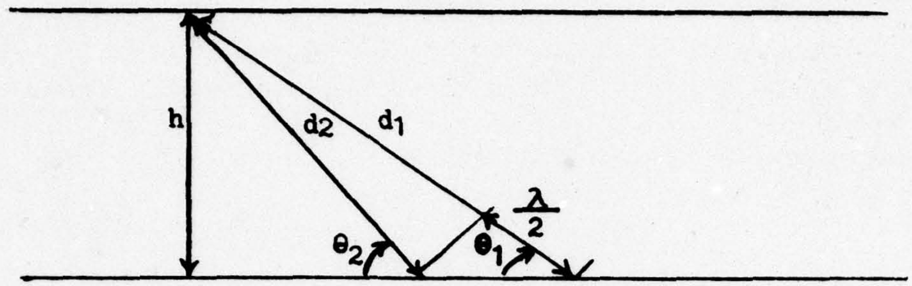
BOTTOM LOSS IN DB / REFLECTION
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0
10
20
30
40
50
60
70
80
90
CONFIDENTIAL

APPENDIX A



$\lambda = 1.18$ ft $\quad \theta_1 = 30^\circ \quad \theta_2 = 32.5^\circ \quad d_1 = d_2 + \frac{\lambda}{2}$

$$\sin\theta_1 = \sin 30^\circ = \frac{h}{d_1} = \frac{h}{d_2 + \frac{\lambda}{2}}$$

$$\sin\theta_2 = \sin 32.5^\circ = \frac{h}{d_2}$$

$$h = \frac{\sin 30^\circ}{\sin 32.5^\circ} \cdot h + \frac{1.18}{2} \cdot \sin 30^\circ$$

$$h - \frac{.5000}{.5373}\ h = \frac{1.18}{4}$$

$$.0695\ h = 0.295$$

$$h \approx 4.2 \text{ ft.}$$

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(a) Mackenzie, K. V., "Reflection of Sound from Coastal Bottoms", The Journal of the Acoustical Society of America, Vol. 32-2, pp 221 - 231, February 1960

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